Influence of Submerged Breakwater on Longshore Currents

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**Abstract.** Submerged breakwater is a kind of commonly used maritime sheltering structures, so it is necessary to accurately grasp the hydrodynamic characteristics before and after the submerged breakwater. Based on the longshore current experiment in harbor, taking the trapezoid submerged breakwater as the research object, this paper analyzes the influence of submerged breakwater on the mean longshore current by changing the position of submerged breakwater and observes the effect of submerged breakwater on the instability of longshore currents for frequency fluctuation. The results show that the closer the submerged breakwater, cross-shore longshore current velocity has the more obvious tendency to toward the shore. Meanwhile, it will make the upstream direction of longshore current velocity increase and will make the distribution of longshore current velocity in the direction of the whole coast is more uniform. Furthermore, some frequency fluctuation of longshore current instability may strong and new high frequency components of the instability of longshore currents may occur for the increase of the submerged breakwater.

**Introduction**

Submerged breakwater is a kind of protection building which is built in coastal roughly parallel to shoreline and the top submerges below sea level. Submerged breakwater can reflect and transmit some part of wave\cite{1,2}, avoid the erosion of toe of levee by the total reflection and promote the wave split to produce high-frequency components to transfer wave energy. At the same time, the destructive wave is broken ahead of time to stabilize the water area behind the breakwater, so as to prevent the erosion of the coast\cite{3,4}. In addition, because it is located below the water surface, does not affect the coastal landscape, in line with the water loving wishes of the people, the submerged breakwater has gradually become a commonly used revetment. For this reason, many scholars have carried out extensive research on submerged breakwaters. Cho et al\cite{5} studied on the reflection of regular waves on a submerged breakwater on a flat bottom through experiment. Jeng et al\cite{6} studied the propagation and deformation of waves passing through a submerged breaker in front of straight wall. Li Peng\cite{7} studied the propagation and breaking of waves on submerged breakwaters. Jiang Changbo et al\cite{8} made an experimental study on the propagation and deformation of waves passing through the submerged breakwater on the slope. Chen Jie\cite{9} carried out the research on the interaction between wave and submerged breakwater for slope bed, made an analysis of the relationship between energy evolution of double frequency and the water depth of crest under the same incident wave conditions. Rambabu and Mani\cite{10}studied the influence of submerged breakwater crest depth, crest width, incident wave elements on the transmission coefficient of the submerged breakwater by numerical simulation. Liu Zhongbo et al\cite{11} studied the propagation process of wave passing through submerged breakwater on flat bottom based on Boussinesq equation. The above results are mainly focused on the wave propagation, reflection and transmission of submerged breakwater, the researches on the
influences of submerged breakwater to longshore currents including mean longshore currents and the instability of longshore currents are still less. Therefore, it is necessary to carry out research on the influences of submerged breakwater to mean longshore current and the instability of longshore current, which directly affect the coastal sediment transport and pollutant emissions, and was closer to the engineering practice. Based on the longshore current experiment in harbor, this paper analyzes the influence of submerged breakwater on the mean longshore current by changing the position of submerged breakwater and observes the effect of submerged breakwater on the instability of longshore currents for frequency fluctuation. So as to better guide the construction of coastal engineering.

Experimental Setup

The experiment was conducted in the wave basin of the State Key Laboratory of Coastal and Offshore Engineering[12], Dalian University of Technology, which is 55m long, 34m wide and 1.0m deep. In order to study the influences of submerged breakwater to the mean longshore currents and the instability of longshore currents, the distributions of alongshore velocity and cross-shore velocity of longshore current are measured in the experiment for slope 1:40. The beach was rotated at 30\(^\circ\) with respect to the wave-maker so as to increase the beach length, which also made the instability of longshore current have more room for development. The slope length is 18.0m and the water depth in the horizontal bottom in front of the beach is 0.45m. The shortest distance is 8.0m and the longest distance is 22.5m from the foot to wave plate. Two wave guide walls were conducted on the side boundaries on the horizontal bottom part of the flow region. The wave absorbing layers formed by net boxes filled with plastic scraps were placed on the inner side of to prevent the wave reflection against the walls. The coordinate system (x, y) with the origin at upstream end of still water shoreline was adopted with x-axis directing offshore and y-axis downstream, as shown in Figure 1. The channel width is 4.4 m at the two sides of the beach and 4.0 m to 8.0 m behind the beach. The channel water depth is the same as that in the horizontal bottom in front of the beach, 0.45m. The flow in the downstream channel will be driven by the longshore currents and goes through the channel behind the beach model to reach the upstream channel. Then, it feeds into the upstream end to form a closed flow circulation. Figure 1 (Bottom) shows the experimental topography in the vertical direction. Figure 2 shows a submerged breakwater at a certain distance from upstream, and gives a stereogram of single submerged breakwater (Top) and experiment layout (Bottom).

The velocity of the longshore current is measured by ADV produced by Nortek, and the measurement precision is 0.5%× measurement range±1mm/s. A total of 28 velocity meters (ADVs) were used for velocity measurement. Due to larger number, greater distance, ADVs adopt wireless communication, as shown in Figure 3. The vertical distance from bottom of each ADV is 1/3 local water depth for the measurement of depth-average velocity. They are divided into two sets, one being arranged in the longshore direction to measure the uniformity of longshore current; the other being arranged in the cross-shore direction to measure the cross-shore distributions. Figure 4 shows the detailed layout of ADVs in the entire area. The alongshore ADVs are located near the maximum velocity of longshore current, at x=2.5m from the coastline. The alongshore positions of ADVs were from first y=2.5m to eleventh y=22.5m with interval 2.0m. In order to obtain the distribution characteristics of the longshore current velocity profile better, a lot of current meters are arranged on the shore side due to the distribution of cross-shore velocity is narrow. The distance from the measuring point to static waterline in the direction perpendicular to the shoreline were 0.2m, 0.6m, 1.0m, 1.3m, 1.6m, 2.0m, then from 2.0m to 7.0m with interval 0.5m and from 7.0m to 9.0m with interval 1.0m. The alongshore position which is perpendicular to the shoreline located at y=14.5m.
Figure 1. Experimental set-up and bottom profile.

Figure 2. Stereogram of single submerged breakwater (Top) and experiment layout (Bottom).

Figure 3. Communicate through wireless way for ADV.
Influence of Submerged Breakwater on the Mean Longshore Currents

The influence of the offshore distance of the submerged breakwater on the cross-shore velocity distribution of longshore current and its alongshore uniformity is discussed under the condition of different wave conditions, and the specific conditions are shown in Table 1. The left and the right of Figure 5 give respectively the cross-shore velocity distribution and alongshore velocity distribution of longshore current where the submerged breakwater located at $x=3.5\text{m}$, $4.0\text{m}$, $4.2\text{m}$ and $4.5\text{m}$ for three kinds of wave conditions in Table 1. Figure 5 shows that the cross-shore velocity distributions of longshore current entirely move toward the shore during the process of offshore distance of submerged breakwater decreased from 4.5m to 4.0m for Case1 to Case3. The upstream velocity increases along the coast, and the alongshore velocity distribution is more uniform. The above characteristics for Case1 and Case2 are not obvious during the process of offshore distance of submerged breakwater decreased from 4.0m to 3.5m but Case3 is still able to reproduce. This shows that the closer the submerged breakwater, cross-shore longshore current velocity has the more obvious tendency to toward the shore and the position of maximum longshore current velocity changes little in general. Meanwhile, it will make the upstream direction of longshore current velocity increase and will make the distribution of longshore current velocity in the direction of the whole coast is more uniform. It should be pointed out that the influence of the submerged breakwater on the mean longshore current may not be established when the distance from submerged breakwater to the coast is close to a certain extent. This needs to be determined by more model experiments.

Table 1. Wave cases in the experiment.

<table>
<thead>
<tr>
<th>Wave cases</th>
<th>Wave height(m)</th>
<th>Wave period(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case1</td>
<td>0.076</td>
<td>2.0</td>
</tr>
<tr>
<td>Case2</td>
<td>0.083</td>
<td>1.5</td>
</tr>
<tr>
<td>Case3</td>
<td>0.088</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Influence of Submerged Breakwater on the Instability of Longshore Currents

The breaking of waves will cause the movement of horizontal vortex, and the horizontal vortex will be transformed into the vertical vortex, as shown in Figure 6. Here we consider the influence of the vortex motion caused by the wave breaking on the fluctuating frequency of the longshore current instability by increasing the submerged breakwater to increase wave breaking. The structural dimensions of Submerged Breakwater (unit: mm) and outline are shown in figure 2.
Figure 6. Obliquely descending eddies transformed into horizontal eddies.

Figure 7 gives the results of maximum spectrum of time series of alongshore velocities (5 groups) for Case4 (T=1s, H=5.80cm) and Case5 (T=1s, H=10.50cm) under the condition of with and without the submerged breakwater. In which, three groups are without submerged breakwater and the other two groups are with submerged breakwater (showed by the solid line and thick dotted lines respectively in Figure 7). Figure 7 shows that the fluctuation of some frequency with submerged breakwater will be significantly enhanced. For example, at $f=0.019Hz$, the peak energy of the spectrum is increased from $47cm^2s^{-1}$ without submerged breakwater to $167 cm^2s^{-1}$ with submerged breakwater for Case4 and at $f=0.034Hz$, the peak energy of the spectrum is increased from $63cm^2s^{-1}$ without submerged breakwater to $161 cm^2s^{-1}$ with submerged breakwater for Case5. At the same time, a new high frequency part may come out. For example, at $f=0.015Hz$ and at $f=0.029Hz$, new spectral peaks come out with submerged breakwater for Case4 and at $f=0.008Hz$ and at $f=0.024Hz$ for Case5.

Figure 7. Maximum entropy spectrums of velocity time series.

--- --- --- ---:include submerged breakwater (three groups);

--- --- --- --- : not include submerged breakwater (two groups)
Conclusion

This paper analyzes the influence of submerged breakwater on the mean longshore current by changing the position of submerged breakwater and observes the effect of submerged breakwater on the instability of longshore currents for frequency fluctuation. The results show that the closer the submerged breakwater, cross-shore longshore current velocity has the more obvious tendency to toward the shore. At the same time, it will make the upstream direction of longshore current velocity increase and will make the distribution of longshore current velocity in the direction of the whole coast is more uniform. On the other hand, some frequency fluctuation of longshore current instability may strong and new high frequency components of the instability of longshore currents may come out with submerged breakwater.

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References


